FUSION SYSTEMATICS FOR RADIO-ACTIVE/ UNSTABLE NUCLEI USING STELSON MODEL

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Introduction

In recent years, the sub-barrier fusion of neutron-rich nuclei is emerged as one of the exiting and challenging field with the availability of radio-active ion beams. The role of neutron rearrangement in fusion has been investigated in greater length by Zagrebaev [1]. This can be considered as an extension of Stelson model [2]. According to Stelson model, the fusion barriers have been explained by a flat distribution of barriers with a threshold energy cutoff (T). This barrier corresponds to the energy at which the nuclei come sufficiently close to each other for neutron to flow freely between target and projectile.

Based on Stelson model, fusion systematics have been worked out by Stelson[3], Vandenbosch[4], Kailas and Navin[5], A M Vinodkumar[6] etc. In [6], 95 projectile target combination of stable beams were analysed using this model and a good correlation was found when inter-surface distance derived from experimental barriers were compared with theoretical one.

Analysis

In this present study, we have selected 44 projectile and target combinations with radioactive or stable ions with weakly bound nucleons as projectiles. These selected systems span Z_pZ_t range 30-500. Among these selected projectiles, some are radioactive ions with N/Z ratio ≥ 1.5 (^{6,8}He,^{10,11}Be, ^{9}Li etc.) where as others are stable nuclei with weakly bound nucleons. The fusion barrier for each system (B) is found by fitting the above barrier fusion data. To obtain the threshold barrier (T), we have used the value of fusion barrier (B) obtained from above barrier fit and used the expression as given by Stelson[2]. $\sqrt{\sigma E} = (E-T)[(\pi R^2)/4(B-T)]^{1/2}$. After finding the value of B and T, we tried to sort out a relation between barrier width (B-T) and reciprocal of neutron separation energy ($1/S_n$) as suggested by Vandenbosch[4]. The resultant plot is shown in Fig. 1. In this case, we can identify He projectile as a separate group, however, a definite correlation was not seen.

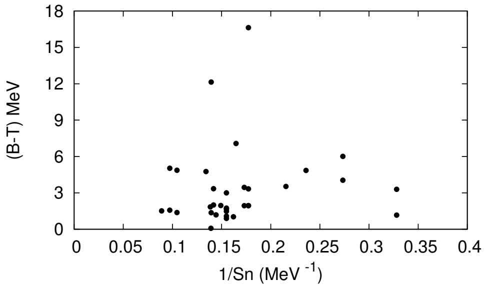

FIG. 1: Barrier distribution width (B-T) is plotted against $1/S_n$ for different projectile target combination.

From B and T values we have extracted inter-surface separation d_{exp} for each projectile target combinations as in [6]. This was compared with inter-surface distance d_{th} calculated from the neutron separation energy. Here d_{th} is related to S$_n$ by $S_n = \frac{-100.0\ MeV}{(1+exp(\frac{d_{th}}{2a}))}$ where, S_n is taken as the half of the two neutron separation energy of either the projectile or the target nuclei, whichever is smaller. Fig. 2 clearly shows that most of the data points lie above the line d_{th}=d_{exp}. As given in [6], in Fig. 3, we have plotted the difference

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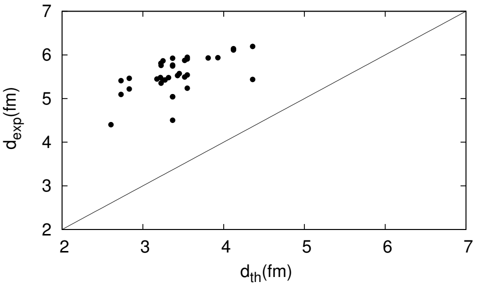

FIG. 2: Inter-surface distance d_{th}, derived from neutron separation energy is plotted against experimental inter-surface distance d_{exp}.

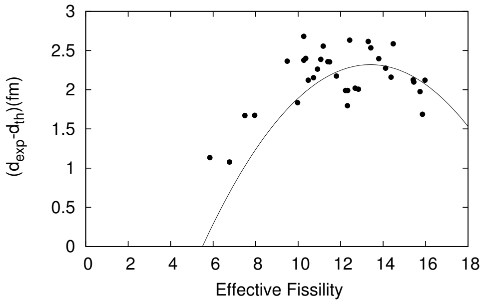

FIG. 3: Plot of system parameter effective fissility, ζ_{eff} against (d_{exp}-d_{th}).

in experimental and calculated values of intersurface distance (d_{exp}-d_{th}) against fissility, ζ_{eff}. Such a system size size dependence was used else where[7].

This dependence was included by redefining the d_{exp} as $d_{exp} = (R_T - s - R_1 - R_2 - \Delta R) - [a_1 + a_2(\frac{Z^2}{A})_{eff} + a_3(\frac{Z^2}{A})^2_{eff}]$ here a_1, a_2, a_3 are fit parameters. After incorporating this system size dependence in d_{exp}, we have replotted d_{exp} against d_{th} in Fig. 4. As shown in figure, the straight line represents most of the data points and clearly shows a strong correlation between d_{exp} and d_{th}. This means there is a strong correlation between neutron separation energy and the threshold barrier in the case of fusion reactions with unstable projectiles as seen in the case of stable projectile target combinations[6]. In the case of He projectiles (such as ^{6,8}He) deviation from systematics was observed. This can be attributed to extened halo behavior of ^{6,8}He nuclei.

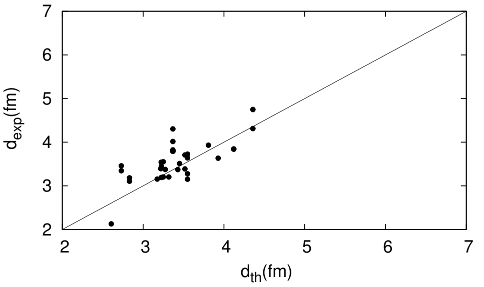

FIG. 4: d_{th} against d_{exp} plot after incorporating the system dependance.

Conclusion

Fusion reactions using radioactive beams or unstable projectile beams have been analysed using neutron flow model (Stelson). A good correlation between the experimental intersurface separation derived from experimental threshold barrier and the the theoretical intersurface separation calculated from neutron separation was found. In the case of two neutron halo nuclei such as ^{6,8}He, ^{11}Li projectiles, further studies are required.

References

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